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DRAWINGS ATTACHED

1 329 971

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(54) ROLLING MILL

(71) We, ALCAN RESEARCH AND DEVELOPMENT LIMITED, a Company incorporated under the laws of Canada, of 1, Place Ville Marie, Montreal, Quebec, Canada, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to rolling apparatus and is particularly directed to a rolling mill for rectifying "bad shape" in rolled products, although a rolling mill may be constructed in accordance with the principles of the present invention for producing rolled products in which "bad shape" is avoided or held to a minimum.

In our British Patent No. 1,134,635 there is described a rolling mill in which the work rolls are thin and flexible and are backed by two or more rows of axially short backing rolls through which the vertical rolling load is imposed on the work rolls. Each of the work rolls is backed by such backing rolls and a substantially equal loading force is applied to each of the backing rolls in each row of backing rolls. The backing rolls also resist the horizontal loads on the work rolls. As described in that specification the force is applied to the backing rolls by means of a hydraulic capsule which extends for the full length of the adjacent work roll. Each of the axially short backing rolls is carried in a common carrier with an adjacent backing roll in another row of backing rolls and each of the carriers is subjected to the pressure of the hydraulic capsule. In order to match the loaded width of the work rolls with the width of the strip being rolled, spring-loaded hooks are provided for the purpose of resisting the whole or part of the force applied to the work roll carriers by the hydraulic capsules.

As described in Patent No. 1,134,635 the carriers for the backing rolls were either guided for vertical movement in the mill frame or were pivoted to the mill frame so that the carriers were held against longitudinal movement by the pivots. The latter arrangement was preferred because it eliminated the possibility of misalignment between the upper and lower work roll which could arise through the slight lateral movement (in the longitudinal direction of the strip path) of the individual carriers in the guideways associated with the mill beam.

It has however been found that very slight misalignment of the pivot axes of the individual roll carriers can lead to unacceptably large errors in the vertical forces applied to the work roll through the backing rolls. It has been shown that non-uniformity of the load to the extent of a few per cent can cause unacceptable bad shape in the product of the flexible work-roll mill described in Patent No. 1,134,635 and that misplacement of the pivots of the backing roll carriers by amounts of only a few ten-thousandths of an inch can cause unacceptable rolling load errors. It would be difficult and costly to avoid misplacement errors of this magnitude.

It is therefore a principal object of the present invention to provide an improved form of rolling mill operating on the same general principles but avoiding the necessity for the extreme accuracy in positioning the pivots of the backing roll carriers.

Another difficulty experienced with the apparatus described in Patent No. 1,134,635 is the possibility of flow of hydraulic fluid to one end of one hydraulic capsule and the other end of the other hydraulic capsule so that the work rolls, although remaining parallel with one another, become misaligned in relation to the mill beams.

In the apparatus described in Patent No. 1,134,635 each of the carriers for the backing rolls is provided with spring-loaded

latches for matching the loaded width of the work roll to the width of the strip passing between the work rolls. It is found that the outermost loaded backing rolls must apply loads to the work rolls adjusted to within about 1/8th. inch of the strip width. Unless the loading applied by the backing rolls is matched with the product width within the above accuracy the strip will have "bad shape" through being either "long edged" or "long middled".

According to a further feature of the invention there is an improved system for matching the loaded width of the work rolls with the width of the product and in particular for adjusting the load applied through the outermost loaded elements to the backing roll which responds automatically to the strip width.

Although in Patent No. 1,134,635 we have described an apparatus in which the backing rolls in one row are staggered in relation to the backing rolls in the adjacent row great difficulty is experienced in manufacturing such apparatus and in practice it has not been found possible by use of this expedient to avoid the formation of marks on the work rolls by the backing rolls.

According to the invention a rolling mill for rolling metal strip comprises a mill frame, flexible upper and lower work rolls, each work roll being backed either directly or through an intermediate roll by a single row of axially short backing rolls, each backing roll being carried in an individual carrier pivoted to a rigid member of the mill frame, the pivots of all the carriers associated with each work roll being aligned with one another, said mill including means permitting the application of a substantially constant loading force to each of said carriers, the work rolls also being contacted by reaction rolls which contact the work rolls in such a manner that the resulting reaction forces are substantially parallel with the plane of the strip pass between the work rolls to absorb the loads which arise in at least one direction parallel to the strip during rolling.

The flexibility of the work rolls should be matched to the purpose for which the mill is to be employed in accordance with the principles already set out in British Patent No. 1,134,635.

Reaction rolls may be provided on both sides of the work rolls and in such case the axes of the backing rolls lie on the plane passing through the axes of the upper and lower work rolls. Alternatively reaction rolls may be employed on one side only of the work rolls, the reaction on the other side of the work rolls being provided by the backing rolls which are so arranged that the line of application of pressure to the work rolls is off-set from the plane passing through the axes of the work rolls, the amount of said offset for each work roll being such that the plane passing through said line and the bite of the work rolls makes a small angle with the plane passing through the axes of the work rolls, said angle being preferably less than 10°.

It is found with the arrangement of the present invention, in which there is only a single row of backing rolls in contact with each work roll, that the accuracy of the alignment of the pivots of the backing roll carriers is no longer as critical as in the earlier apparatus described in British Patent No. 1,134,635. It can be shown that the tolerable pivot misplacements are more than ten times higher than those tolerable in the earlier apparatus and no difficulty is experienced in satisfying these tolerances by conventional workshop practices.

Referring now to the accompanying drawings:—

Figure 1 illustrates an apparatus made in accordance with the principles of the present invention,

Figures 2 and 3 respectively illustrate two different systems for varying the loading applied through the outermost loaded backing roll,

Figure 4*a* illustrates an individual hydraulic cell,

Figure 4*b* illustrates a modified individual hydraulic cell, and

Figures 5*a*, 5*b* and 5*c* illustrate modified forms of apparatus.

Referring now to Figure 1, there is illustrated diagrammatically a rolling mill, from which the main frame elements have been omitted. In the drawing upper and lower main beams are indicated at 1 and 2 to provide the ultimate support for the thin and flexible work rolls 3 and 4, which may be driven rolls or which may be undriven and be turned by contact with the strip which is pulled through the rolls for the purposes of rectification of "bad shape". The loading support for the work rolls 3 and 4 is by means of axially short backing rolls 5, each supported in an individual carrier 6 pivoted to the respective beams 1 and 2 on the pivot axes 7. The longitudinal clearance between the backing rolls 5 is kept as small as possible, consistent with the special requirements of the carriers 6. Typically the axial length of the backing rolls 5 is about 1—2 inches and the space between adjacent backing rolls is of the order of ½ inch. Hydraulic capsules 8 are arranged between the carriers 6 and wedges 9, supported by the respective mill beams 1 and 2 and having an angularity such that their surface is substantially normal to the line of reaction between the work rolls 3 and 4 and their backing rolls 5. In order to overcome the difficulty previously men-

tioned which results in misalignment of the work rolls in relation to the mill beams, one of the hydraulic capsules 8 may be divided into two mutually isolated halves.

Reaction rolls 10 are carried in carriers 11 pivoted to the mill structure along the same pivot axis as the carriers 6. The position of the carriers 11 is adjusted by wedges 12 so as to ensure that the reaction between the work rolls and the reaction rolls is substantially parallel with the strip pass plane indicated at 14.

With this arrangement it is found that the variation of load imparted by the individual backing rolls 5 to their associated work rolls is easily kept within 1 or 2% despite misalignment of the order of 2×10^{-3} inches between the pivot axes of the aligned backing roll carrier pivots. This holds true even though the reaction between the work rolls and the reaction rolls may be as high as 20% of the reaction between the work rolls and the backing rolls 5.

As already explained means must be provided for counterbalancing in whole or in part the force applied to the individual carriers 6 by the associated hydraulic capsule 8. The purpose of such counterbalancing is to off-load all the backing rolls 5 lying outwardly of the edges of the strip under treatment and to permit partial off-loading of the backing rolls 5 which overlap the edges of the strip so that the loading applied through the flexible work rolls at the edges of the strip may be matched to the strip width. The position of suitable latching members is indicated at 15. Such latching members may take the form of spring-loaded hooks, but are preferably constructed as shown in Figure 2 or Figure 3. The arrangements shown in Figures 2 and 3 are equally applicable for use in the rolling mill illustrated in Figure 1 and in the various constructions of rolling mill described in Patent No. 1,134,635.

In the system of Figure 2 a latching bolt 16 is arranged to engage a backing roll carrier 6 at the position indicated by the line 15 to apply a variable lifting force on the carrier 6 so as to counteract or counterbalance in whole or in part the force applied to the carrier 6 by the hydraulic capsule 8. The latching bolt 16 is pivotally connected to a lever 17, the movement of which is limited by upper and lower stops 18. Movement of the lever 17 is due to a hydraulic load cell 19 which is connected by tube 20 to the main hydraulic system of the mill so that the hydraulic pressure in the load cell is substantially constant. The lever 17 is provided with a movable fulcrum 21, which is in contact with it at a point between its connection to the latch bolt 16 and its connection to the load cell 19. The movable fulcrum 21 is controlled through a rod 22 which moves it lengthways in a guideway formed on a stationary member 23 of the main mill frame. It will be readily seen that as the fulcrum 21 is moved to the left from a position directly beneath the centre of the hydraulic cell 19 the force applied to the latching bolts to counteract the loading applied by the hydraulic capsule increases. The rod 22, by means of which the longitudinal position of the fulcrum 21 is adjusted, may itself be moved manually, but is preferably moved in response to guides which sense the position of the edges of the strip being rolled. It is possible to provide a self-centering action in response to inward or outward wandering of the strip edge. In the case of outward wandering the loading of the strip edge applied through the relevant backing roll 5 may be increased to such an extent as to cause slight "long edge" and this would tend to steer the strip back to a central position. Since outward wandering at one edge will be accompanied by inward wandering at the other edge the loading at the other edge is simultaneously decreased to such extent that the second edge is rolled slightly "short edge".

A suitable hydraulic loading cell for use in the system of Figure 2 and of Figure 3 is illustrated in Figure 4*a* and consists of a body 30 having a fluid space 31 provided with a pair of fluid connections 32, which form the only outlet for the space 31 which is otherwise enclosed by the body 30 and a flexible diaphragm 33 held in position on the body 30 by means of a clamp ring 34 held in position by studs 35. The diaphragm 33 preferably carries a member 36 which has an external diameter very close to the internal diameter of the ring 34. The thrust face of the member 36 will usually be coated with a low friction material so as to permit it to be used to apply thrust directly to a lever.

In an alternative construction illustrated in Figure 4*b* the diaphragm 33 is replaced by an axially short enclosed rubber capsule 33*a* which fills the space 31 and is held in position by the inner edge of the ring 34, which overlaps it, a rubber reinforcing gasket 37 being interposed between the ring 34 and the capsule 33*a*.

In the system illustrated in Figure 3 no mechanical latching rods are employed for resisting the hydraulic pressure applied to the backing roll carriers 6. In this construction the extended mattress-like hydraulic capsules 8 are replaced by individual hydraulic load cells of which there is one for each backing roll carrier. These individual load cells are constructed as shown in Figure 4*a* or Figure 4*b*. Those hydraulic load cells which load carriers 6 towards the centre of the mill and which will in consequence never require off-loading may be

connected directly to a common high pressure line, so as to maintain them at a common pressure. All the remaining hydraulic load cells, which back carriers 6, are connected to individual controlling load cells. Thus a carrier-backing load cell is connected to a load cell 43, with which it forms a closed system. In the unit of Figure 3, each load cell 43 is associated with a load cell 40, all load cells 40 being interconnected so as to be maintained at a common pressure. The load cells 40 and 43 are positioned between an abutment surface and a dividing beam 42. Depending upon the position of a movable fulcrum 46 controlled by a positioning rod 47 and bearing against a reaction block 48, the pressure transmitted by the hydraulic load cell 43 to its related carrier-backing load cell can be proportioned in relation to the high pressure transmitted to cell 40 and indeed the slave load cells 43 and their related carrier-backing load cells can in this manner be loaded to any pressure between zero and the pressure of cells 40 or indeed to a higher pressure.

Since the backing rolls 5 are rotatably mounted in the carriers 6, it is inevitable that there is some interval between adjacent backing rolls 5 and where these act directly on the work rolls 3 the areas where the work rolls are in contact with the backing rolls will acquire different surface characteristics from the areas out of contact with the backing rolls unless special measures are taken to prevent this. According to a further feature of the invention the work rolls and the pinion stand through which torque is transmitted to them (if driven) from the main motor are made so as to be longitudinally movable through a distance of some inches and the movement is produced in small increments of about $^{1}/_{8}$th—$\frac{1}{4}$ inch by a screw or similar linear drive mechanism which operates automatically each time the roll force is reduced to zero. Preferably the system employs a low area plunger in the hydraulic system to relieve the system pressure immediately prior to the passage of the tail end of the rolling stock through the mill. This acts as a normal off-loading safety device for the mill and may also be utilized to initiate the movement of the sliding piston stand.

Figures 5*a*, 5*b* and 5*c* illustrate alternative arrangements of the mill of Figure 1. Like parts are indicated by like reference numerals. In these arrangements intermediate rolls 50 are interposed between the backing rolls 5 and the work rolls 3 and 4. In Figure 5*a* the axes of these rolls all lie in the same plane. The intermediate rolls 50 and work rolls are retained in position by continuous reaction rolls 51 and 52. The reaction rolls 51 and 52 are supported in continuous semi-circular plain bearings or alternatively by closely adjacent roller bearings. The reaction rolls 51, 52 are thus held rigidly against sagging and against bending in the plane of the strip, those on the entry side of the mill being reactively fixed, but adjustable for roll positioning, whilst those on the exit side are carried in slides and are stabilised by preloading rams 53, 54. In Figures 5*b* and 5*c*, the backing rolls 5 are offset from the plane of the work roll axis, the intermediate rolls 50 thus providing steady continuous horizontal reactions which are supported by the reaction rolls 52. The total number of beams and reaction rolls so needed is reduced from those in Figure 5*a* as indicated, and further, the reaction rolls 51 (Figure 5*a*) are no longer required as roller bearings 55 (Figures 5*b* and 5*c*) impinge directly onto the intermediate rolls 50. The ends of the intermediate rolls 50 are held captive to prevent movement when the work rolls 3, 4 are removed, the latter being counterbalanced to maintain the roll gap.

WHAT WE CLAIM IS:—

1. A rolling mill for metal strip comprising a mill frame, flexible upper and lower work rolls, each work roll being backed either directly or through an intermediate roll by a single row of axially short backing rolls, each backing roll being carried in an individual carrier pivoted to a rigid member of the mill frame, the pivots of all the carriers associated with each work roll being aligned with one another, said mill including means permitting the application of a substantially constant loading force to each of said carriers, the work rolls also being contacted by reaction rolls which contact the work rolls in such a manner that the resulting reaction forces are substantially parallel with the plane of the strip pass between the work rolls to absorb the loads which arise in at least one direction parallel to the strip during rolling.

2. A rolling mill as claimed in claim 1 wherein reaction rolls are provided on both sides of each work roll and the axes of the backing rolls lie on the plane passing through the axes of the work rolls.

3. A rolling mill as claimed in claim 1 wherein a single row of reaction rolls is provided on one side of each work roll, the reaction on the other side of the work rolls being provided by the backing rolls which are so arranged that the line of application of pressure by the backing rolls to the work rolls is offset from the plane passing through the axes of the work rolls, the amount of said offset for each work roll being such that the plane passing through said line and the bite of the work rolls makes a small angle with the plane passing through the axes of the work rolls, said angle being preferably less than 10°.

4. A rolling mill as claimed in any preceding claim wherein means are provided for varying the loading force applied to at least the carriers near the ends of the work rolls.

5. A rolling mill as claimed in claim 4 wherein the means provided for varying the load applied to a particular carrier includes a latching bolt which engages the carrier and to which a variable compensating force can be applied to counteract in whole or in part the force applied by the loading means.

6. A rolling mill as claimed in claim 5 wherein the compensating force is applied by an hydraulic load cell through a lever arrangement attached to the latching bolt, said lever arrangement having a movable fulcrum.

7. A rolling mill as claimed in any preceding claim wherein the means for applying a loading force to the carriers comprises upper and lower hydraulic capsules for the carriers associated respectively with the upper and lower work rolls.

8. A rolling mill as claimed in claim 7 wherein one of said capsules is divided into two mutually isolated parts.

9. A rolling mill as claimed in any one of claims 1 to 4 wherein the means for applying a loading force to the carriers includes individual hydraulic load cells.

10. A rolling mill as claimed in claim 9 wherein the hydraulic load applied by at least some of said load cells is controllably variable.

11. A rolling mill as claimed in claim 10 wherein the hydraulic load cell associated with a carrier is controlled by a unit which includes a slave hydraulic load cell, to which the hydraulic load cell is connected in a closed system and a master hydraulic load cell connected to all other master load cells, each master load cell and slave load cell bearing against a lever having a movable fulcrum, whereby the pressure in the carrier load cell may be maintained at a desired proportion of the master load cell pressure.

12. A rolling mill as claimed in claim 6 or claim 11 wherein the fulcrum is movable automatically in response to guides which sense the position of the edges of the strip being rolled.

13. A rolling mill as claimed in claim 2 wherein the reaction rolls on the side of the work rolls remote from the strip input are carried in slides and are stabilized by preloading rams.

14. A rolling mill as claimed in any preceding claim wherein the work rolls are mounted so as to be longitudinally movable.

15. A rolling mill as claimed in claim 14 wherein the work rolls are connected to a linear drive mechanism which operates automatically to effect a small longitudinal movement each time the roll force is reduced to zero.

16. A rolling mill as claimed in claim 1 and substantially as herein described with reference to and as illustrated in the accompanying drawings.

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1329971 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.

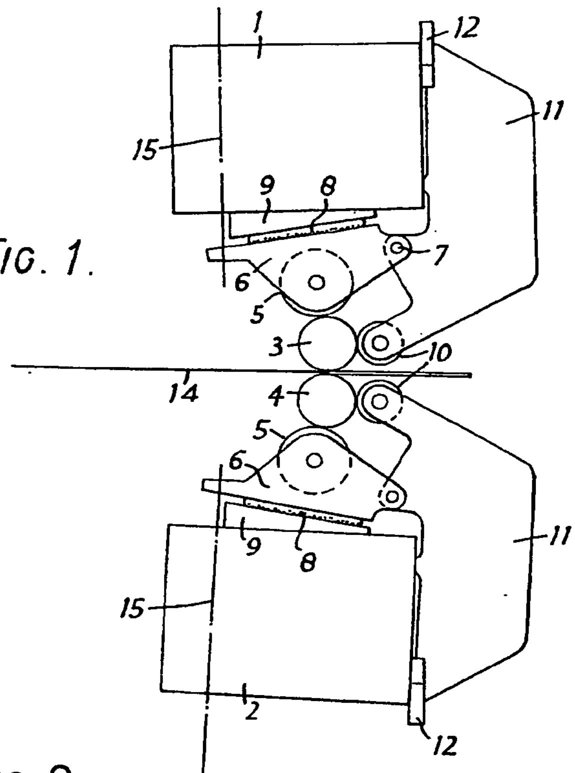


FIG. 2.

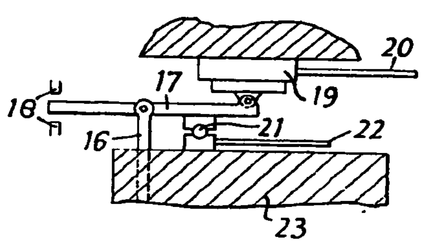
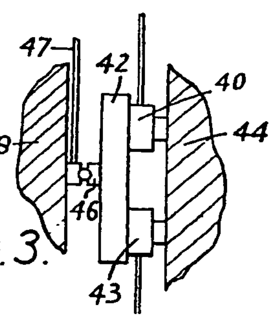


FIG. 3.



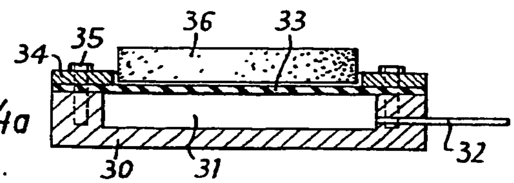


FIG.4a

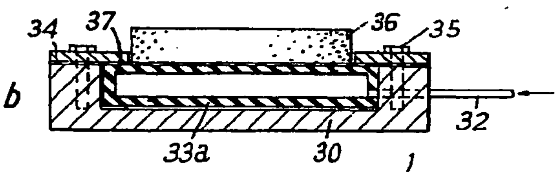


FIG.4b

FIG.5a

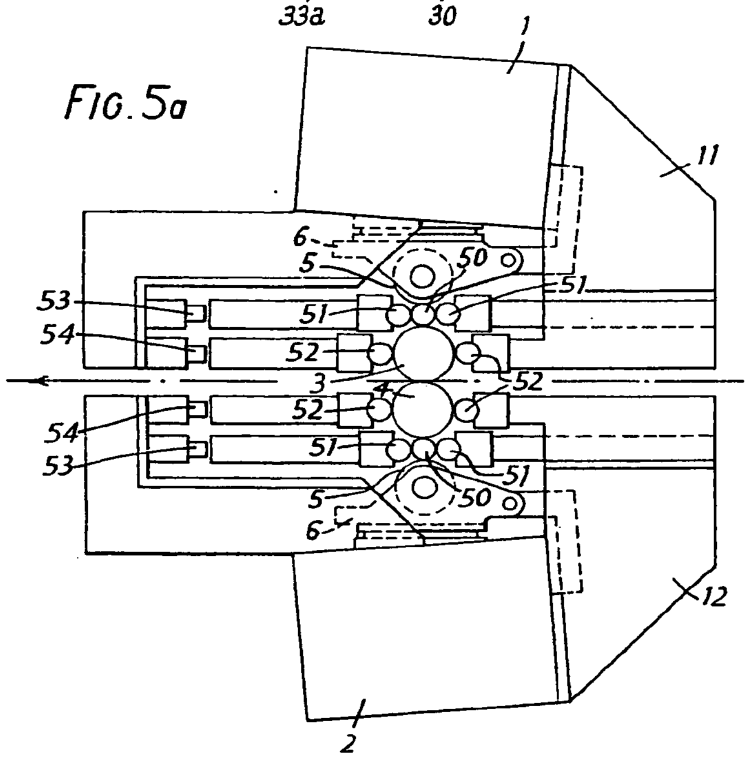


FIG.5b

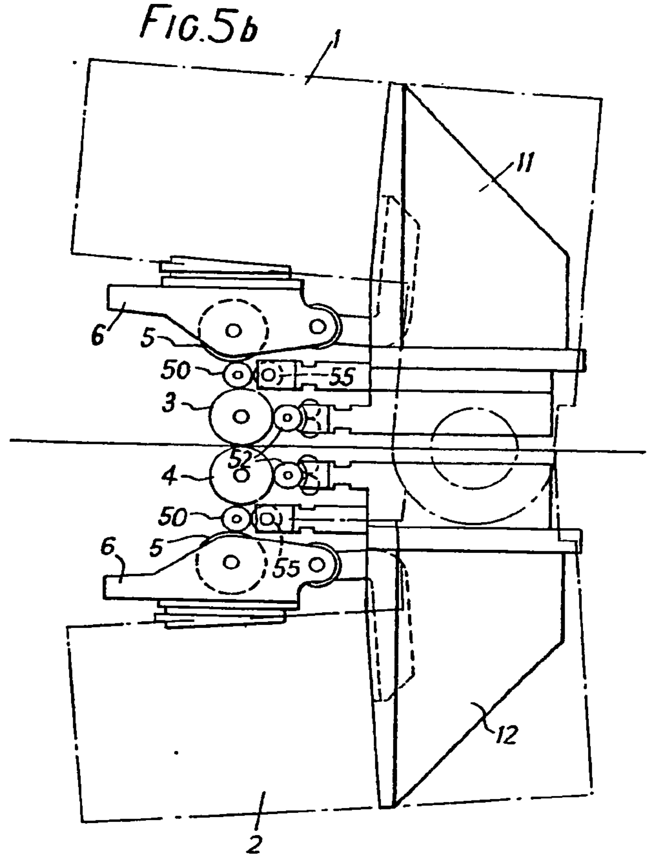


FIG. 5c